



Overview of Tunnel Boring Machines and Testing Devices for Drag Bitsⁱ

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ABSTRACT

The given article is written for the general overview of tunnel boring and testing devices for drag bits. This is about the working principles of TBM, also it describes the materials, which are used in cutting tool and the developments related to wearing out of cutting instrument. They are defined, and their pros and cons also mentioned. Author hopes, the information which introduced in given article will be useful for engineer in this field.

Keywords: tunnel boring; drag bits; Tungsten and Titanium carbide; wearing and cutting.

1. INTRODUCTION

A tunnel boring machine (TBM), is a machine used to excavate tunnels with a circular cross section through a variety of soil and rock strata. They can bore through anything from hard rock to sand.

1.1. History

The first successful tunneling shield was developed by Sir Marc Isambard Brunel to excavate the Thames Tunnel in 1825. However, this was only the invention of the shield concept and did not involve the construction of a complete tunnel boring machine, the digging still having to be accomplished by the then standard excavation methods. [1]

The first boring machine reported to have been built was Henri-Joseph Maus' Mountain Slicer. Commissioned by the King of Sardinia in 1845 to dig the Fréjus Rail Tunnel between France and Italy through the Alps. [1]

1.2. Types of tunnel boring machines

- 1) The single shield TBM is used for digging tunnels in hard rock formations (fractured rock, soft rock). With this technology, boring and segment fitting are not simultaneous. The cutter head, equipped with disc cutters which fracture the rock, extends to excavate the tunnel. Then, the erector installs the segment ring to build the tunnel. The excavated material is brought to the surface by conveyors. [2]
- 2) The slurry TBM. In highly unstable terrain, face pressure during tunneling is maintained by counterbalancing the pressure with bentonite slurry, which forms a mud cake at the tunnel face. The front shield of the TBM is filled with excavated

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material, except for one air-filled part. The pressure within this air bubble is subject to fine control. [2]

3) The EPB TBM (Earth Pressure Balance tunnel boring machines) permits to excavate tunnels in soft ground conditions (clay, silt, sand...). The front shield of the machine is filled with debris extracted by a screw conveyor. This screw compensates the pressure difference between the bulkhead chamber and the atmospheric pressure. Foam injection renders the material more homogeneous, thus facilitating its excavation. [2]

4) The dual-mode TBM is developed to receive two types of removal equipment, each one corresponding to a given type of ground. In this example, the TBM can either operate in open mode as a hard rock shield machine in self-supporting rock or in closed mode as an EPB machine in unstable soil conditions. [2]

5) The double shield TBM allows faster tunnel excavation in hard rock formations as the segments are installed during excavation. The rotating cutter head cuts the rock (front shield advance) and, simultaneously, the telescopic shield advances to lay the tunnel lining. [2]

2. MATERIAL OF CUTTING TOOLS (DRAG BITS)

2.1 Tungsten carbide (WC)

Tungsten carbide (WC) is actively used in the art for the manufacture of tools requiring high hardness and corrosion resistance as well as wear-resistant surfacing, working in heavy abrasive wear with moderate shock loads. This material is used in the manufacture of various cutting tools, grinding wheels, drills, cutters, drill bits and other cutting tools.

2.2 Titanium carbide (TiC)

Titanium carbide, TiC, is an extremely hard (Mohs 9-9.5) refractory ceramic material, similar to tungsten carbide.

This material is sometimes called high-tech ceramics.

The resistance to wear, corrosion, and oxidation of a tungsten carbide-cobalt material is very high.

3. TESTING DEVICES FOR DRAG BITS

3.1. The NTNU Abrasion Test (Norway)

In the Fig.1 is tribo device from Norway. On rotation disk supply abrasive. The devices have low rotation speed. If rotation speed is fast, then abrasive can to fly down. Sampel has done with rounded edge. This is been doing for free going abrasive under to sample [3]. On the devices can to use only one sample, this is disadvantag for the devices. During the experiment can't to compared wear between different samples. More Disadvantag for the devices is low rotation speed. About the Disadvantag mentioned earlier. Advantages for the devices is:

- Fresh abrasive
- Abrasive of different sizes

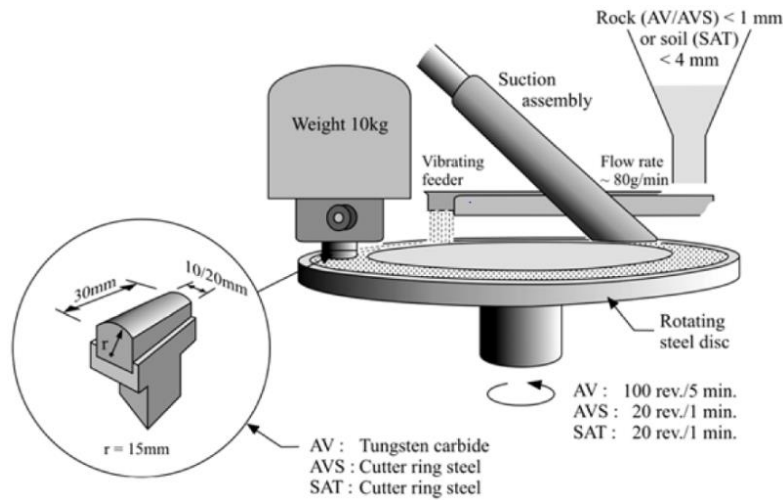


Fig. 1. Tribo-testing devices NTNU. The devices can to explore for abrasive wear.

3.2. High/low stress abrasion device with adjustable inert. Multifunctional modular tribosystem (MMTS) (Estonia).

The devices made also for abrasive wear testing. The device is shown in Fig 2.

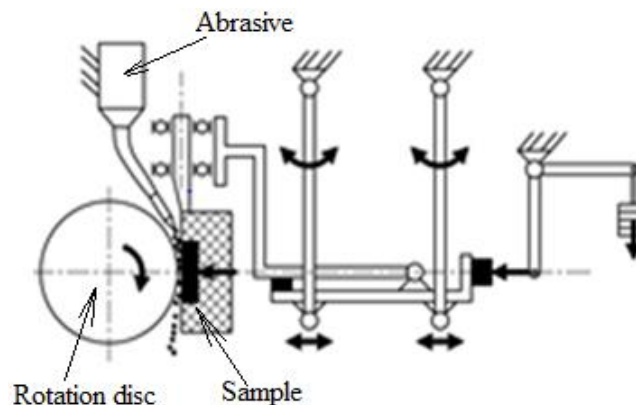


Fig. 2. Block-on-ring tribo-testing devices MMTS.

Abrasive supply between disc and samples. In the devices is cooling system for sample. Rotation disc can to be from rubber for low stress abrasion, and disc can to be from steel for high stress abrasion. For correct high stress abrasion experiment shall be constructed a rotation disc of a hard metal or an alloy. This is disadvantage for the devices. For the systems is max rotation speed 700 rpm. For the sample max pressure force is 200N [4]. This device can be used only 1 sample. Experiment can to carry out with high temperature.

3.3. Pennstate soil abrasion testing device (USA)

The device consists of a cylindrical chamber 350 mm in diameter and 450 mm in length. The chamber dimensions were selected to allow for soils potentially containing large gravel-cobble size particles, to simulate the in-situ conditions of the soil as closely as possible and avoid altering grain size distribution as in some other tests (Fig. 3). The chamber is partially filled with the soil sample. The propeller, which is intended to

create maximum contact forces with the soil, is attached to a drive shaft and rotates inside the cylindrical chamber. Max rotation speed of the propeller is 60 rpm. The propeller has three blades with the radius of 150 mm that are welded at an angle of 120° on a cylindrical base. This leaves an annular space of about 12 mm between the edge of the propeller blades and the walls of the chamber that allows for limited material flow inside the chamber. During the test, the propeller is located 150 mm from the chamber base, covered by soil on top of the blades. The setting leaves the propellers surrounded by soil on top and bottom and provides some space for soil to move around if the rheological properties of the soil allow for any such movements. The chamber is constructed as a pressurized chamber having the capability of performing tests under ambient pressures of up to 10 bars.” [5]

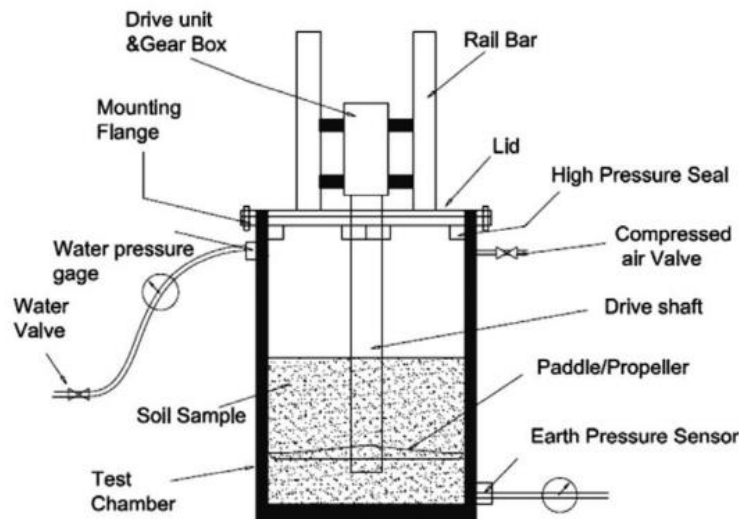


Fig. 3. Pennstate soil abrasion testing device.

4. CONCLUSION

The application of TBM all over the world is widespread. The TMB are generally used for subways and tunnels creation, which connect the roads through mountains and cliffs. The cutting instrument quickly glows blunt because of rock solidity.

The goal of my doctor's work is searching of optimal solutions for devices, which are used for testing and research of wearing out of cutting instrument. For optimal solution search, we must study the movement of abrasive particles of cutting instruments, which are really used. Then we must imagine it in laboratory conditions. This is quite hard task, because in the real conditions it is very difficult and dangerous to measure the movement of particles. I would even say, this is impossible, because it is impossible to get to cutting mechanism during its application process. It is rather necessary to create smaller copy of TBM cutting shield, and to apply it for research.

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CONFLICT OF INTERESTS

The author declares that there is no conflict of interest regarding the publication of this research article.

REFERENCES

- [1] Bagust, Harold (2006). THE GREATER GENIUS A BIOGRAPHY OF MARC ISAMBARD BRUNEL. Ian Allan Publishing. p. 65.
- [2] <http://www.nfm-technologies.com/-Underground-work-.html> 20.11.2012
- [3] B. Nilsen, F.Dahl, J.Holzhäuser, P.Raleigh (2007). NEW TEST METHODOLOGY FOR ESTIMATING THE ABRASIVENESS OF SOILS FOR TBM TUNNELING. p.104-116
- [4] M.Antonov, I.Hussainova, E.Adoberg (2012). EFFECT OF LOADING SYSTEM INERTIA ON TRIBOLOGICAL BEHAVIOUR OF CERAMIC-CERAMIC, CERAMIC-METAL AND METAL-METAL DRY SLIDING CONTACTS. p 10.
- [5] J. Rostami, E. A. Gharahbagh, A. M. Palomino, M. Mosleh (2011) Development of soil abrasivity testing for soft ground tunneling using shield machines. p. 246-256